QUALITY PROCEDURES OF SOLARGIS FOR PROVISION SITE-SPECIFIC SOLAR RESOURCE INFORMATION

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Abstract

This work demonstrates the ability of SolarGIS database to provide high-quality DNI information for a project-specific site characterization. Two aspects of DNI are presented: (1) standalone database quality, as compared to high-quality ground measurements in the Mediterranean region; (2) site-enhanced quality, using a shorter period of local ground-measured data to reduce bias and deviations in a probability distribution function in all years that are included in the satellite database.

Keywords: Direct Normal Irradiance, quality, SolarGIS.

1. SolarGIS data and online system

SolarGIS (http://solargis.info/) is a new generation web service offering a range of unique features. The core of the system is based on (i) a new high resolution database of solar radiation and air temperature; both are operationally built from satellite and meteorological sources, (ii) fast and easy geographical navigation using interactive maps, (iii) tools for accessing and display of data. At present the data geographically cover major parts of Europe, Turkey, North Africa and Middle East. Until end of 2010 the extent will cover complete continent of Africa.

1.1. Solar resource database

A new model for high-performance calculation of Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI) from satellite was implemented for Europe, Middle East and Africa [1]. The model is designed for operational processing of Meteosat MSG satellite data (© 2010 EUMETSAT) at full spatial and temporal resolution, geographically covering Europe, Middle East and Africa. The algorithms are based on the Heliosat-2 calculation scheme [2] and the approach of [3].

The key enhancements of the new model include: (1) multi-spectral satellite information to improve classification of snow/land/cloud signals, (2) a new algorithm to more accurate calculation of lower bound preserving diurnal variability, (3) implementation of backscatter correction (4) variable upper bound for dynamic range and cloud index calculations, (5) new clear sky model, adapted DirIndex model for calculation of DNI from Global Horizontal Irradiance, and (7) downscaling with high resolution DEM to include local variability of solar irradiance (algorithm published recently by [4]).

A new broadband simplified version of the SOLIS model [5] is implemented in the calculation scheme. This model allows fast calculation of clear-sky irradiance from three input parameters characterizing the state of the atmosphere: water vapour, aerosol content and aerosol type (urban, rural, maritime and tropospheric).

Two global atmospheric data sets are implemented in the clear-sky model: water vapour (WV) and Atmospheric Optical Depth (AOD), both received from ECMWF [6] (© 2010 ECMWF). New AOD data set is one of the main outcomes of the European project GEMS. It better captures daily variability, especially events with extreme atmospheric load of aerosols and water vapour. Thus it reduces uncertainty of instantaneous GHI and especially DNI estimates. Main accuracy improvements were achieved in reduction of Root Mean Square Deviation (RMSD) and improved distribution functions.

Solar radiation data are available from March 2004 onwards at 15-minute or aggregated time domains, in high spatial resolution.

Besides solar radiation, also air temperature is available. This parameter is derived by disaggregation of ECMWF ERA Interim data to a final grid resolution 1 km. In the disaggregation high-resolution digital terrain model SRTM-3 is used to adapt vertical gradient of temperature from low resolution ERA grid cells to 1-km grid. Primary data include 6-hourly values covering a period from 1991 onwards. By temporal interpolation, 15-minute time steps are calculated from the primary data in SolarGIS applications. Accuracy of monthly statistics was validated using observations from more than more than 700 ground stations: mean bias is close to 0.1°C and RMSD is ranging between 0.4° and 0.6°C.

1.2. Online access

Access to the data is managed via a map-based interface with geographical search functionality exploiting Google Maps API (© 2010 Google). This service offers to solar energy industry a unique and standardized access to primary (GHI, DNI and air temperature) and derived solar radiation data available at various time scales – from yearly and monthly averages to daily, hourly and 15-minute values.

SolarGIS is designed to provide a users fast access to key information needed for a site selection or comparison. Map-based technology shows information in a spatial context, thus a user can better understand regional changes of solar resource and air temperature resulting from the proximity to a seaside, mountains, terrain shading, elevation, etc. Three online applications are implemented: iMaps, climData and pvPlanner.

The *iMaps* application enables interactive browsing of maps (spatial resolution up to 250 metres): solar radiation and temperature from a continental to local scale. Other support maps are also available: terrain, land cover, population and standard Google maps. For any point clicked on a map, the system interactively shows values of annual solar radiation (global horizontal, global irradiation for 30° and for 2-axis tracking surfaces, diffuse and direct normal irradiation) and air temperature (yearly average, January and July). In addition, support information about terrain, land cover and population are also displayed.

The *climData* application offers historical averaged data, as well as time series for a selected time period and temporal resolution up to the recent history for any selected site. The data represents period 2004 up to the present time. A user can choose different primary data parameters (GHI, DNI and air temperature) and time scales. Data are available in xls, csv and pdf formats and they are compatible with most used design software. A new release is under preparation offering data in near-real time for sites with existing solar energy installations, enabling thus support to performance monitoring and audit.

The third application *pvPlanner* relates to simulation of photovoltaic power systems, and it is not discussed here in details.

2. Quality assessment of DNI

Satellite-derived Direct Normal Irradiance is compared with high-quality ground measurements from 29 BSRN and meteorological stations over Europe and North Africa. The quality standards defined by the IEA SHC Task 36 and MESoR [7] and standardization proposals of [8] are considered.

The mean bias of DNI is -3.1 W/m^2 (-0.9%), standard deviation of biases 6.4% and Root Mean Square Deviation (RMSD) is 123, 75, and 32 W/m^2 (35.7%, 21.9% and 9.3%), for hourly, daily and monthly data, respectively.

In Spain, the model was validated against data from 14 ground stations. The mean bias is 16.4 W/m^2 (4.2%), standard deviation of biases 3.9%, and hourly RMSD is 110 W/m^2 (32.2%). However for sites in desert (Tamanrasset and SedeBoqer) the quality validation shows higher deviation: mean bias is -26 and -71 W/m^2 (-4.2 and -11.7%), respectively, and RMSD is 144 and 174 W/m^2 (23.3 and 28.4%) respectively.

Despite the fact that the use of database of daily AOD values significantly improved the DNI simulation, especially the frequency distribution of high DNI values, it was found that the main source of deviation between the ground-measured values and the satellite estimates in the desert sites are inaccuracies of atmosphere parameterization in GEMS AOD raster database (as compared to the AERONET data).

3. Enhanced DNI accuracy: combining satellite DNI with short-term, high quality ground measurements

Combining satellite data with local ground measurements aims to improve accuracy of the integrated solar irradiance values and time series. A common problem of satellite derived DNI databases is disagreement of frequency distribution functions (compared to ground measurements ones), that limits the potential to record the occurrence of extreme situations (e.g. very low atmospheric turbidity resulting in high DNI). Therefore the enhancement of satellite databases using the ground measurements focuses (i) on the improvement of the overall bias as well as (ii) the fit of frequency distribution functions.

The enhancement of the DNI accuracy is usually done for the satellite data covering a longer period of data (e.g. several years) using high-quality ground measurements which cover shorter period of time, usually several months to one year. This type of enhancement assumes that the systematic error/deviation exists in the satellite data and the magnitude of this deviation is invariant over the time. An example of such data set is Sede Boqer site, where the GEMS AOD dataset used in the satellite model shows a systematic overestimation compared to the site measurements from AERONET dataset. This AOD discrepancy reflects the local site-specific conditions that may not be correctly represented in the low resolution (approx. 100 km) GEMS aerosol dataset. However, the ground measurement campaign has to be long enough to be a representative compared to the type of deviation present in the satellite-derived database. In other words, if the ground data are not capable to cover the type of the deviation to be corrected, such enhancement may result in a degradation of the overall satellite data accuracy.

On the example of five ground stations (Sede Boqer in Israel, Tamanraset in Algeria, Payerne in Switzerland, and Badajos and Cordoba in Spain), two types of correction are made:

1. For prefeasibility studies, DNI long-term monthly and annual averages are calculated using correction of bias;
2. For feasibility studies and due diligence, enhanced hourly and 15-minute time series are produced with corrected cumulative probability distribution function.

For both procedures, year 2005 is used for the calibration of the correction coefficients, and all other years of data are used for *validation*. Effects of atmospheric parameters (AOD, WV), cloud index and cloud variability are analysed. For the assessment of the enhancement procedures, three deviation measures are used:

- Measures based on the comparison of the all pairs of the hourly data values: Mean Bias Deviation MBD, and Root Mean Square Deviation RMSD in relative form (divided by the mean DNI value)
- Measure based on the difference of the cumulative distribution functions: KSI (according to [7]).

4. Results

For all selected sites, an improvement was achieved in the sense of overall bias and/or cumulative frequency functions (Tab. 1, Fig. 1), especially for sites with high deviation.

The case of the Sede Boqer clearly shows that the large systematic error in modeled DNI may be effectively removed by both enhancement methods. For all sites the simple de-biasing procedure only slightly improves the match of cumulative distribution functions. The procedure based on the fit of the distribution functions has potential to correct also bias, especially for larger deviations.

The results for Badajos show that the deviation of the ground measurements and data derived from the satellite model in year 2005 is not representative, and the enhancement of the satellite derived DNI increases the bias for the rest of the ground measurement data for both correction methods. This may be result of the specific source of deviation seen in the 2005 data subset (e.g. exceptional atmosphere state), but more likely it indicates a problem of ground sensor instrumentation.

	Orig. MBD [%]	Orig. RMSD [%]	Orig. KSI [%]	Debias MBD [%]	Debias. RMSD [%]	Debias. KSI [%]	Freq. cor. MBD [%]	Freq. cor. RMSD [%]	Freq. cor.. KSI [%]
Tamanrasset	-4.1	23.3	297	-3.4	21.9	225	-3.2	22.3	53
Sede Boqer	-11.7	28.4	299	2.4	36.9	76	2.1	37.2	63
Payerne	-1.2	32.6	117	-2.0	33.4	116	-2.1	34.8	33
Badajos	7.0	26.9	137	7.7	35.9	121	8.4	36.7	44
Cordoba	8.9	32.2	117				1.3	31.1	21

Tab. 1 Comparison of original satellite model results with corrected outputs. (Orig – original dataset deviations for all ground measurements, Debias – simple debiasing method, Freq.cor. – correction of frequency distribution function)

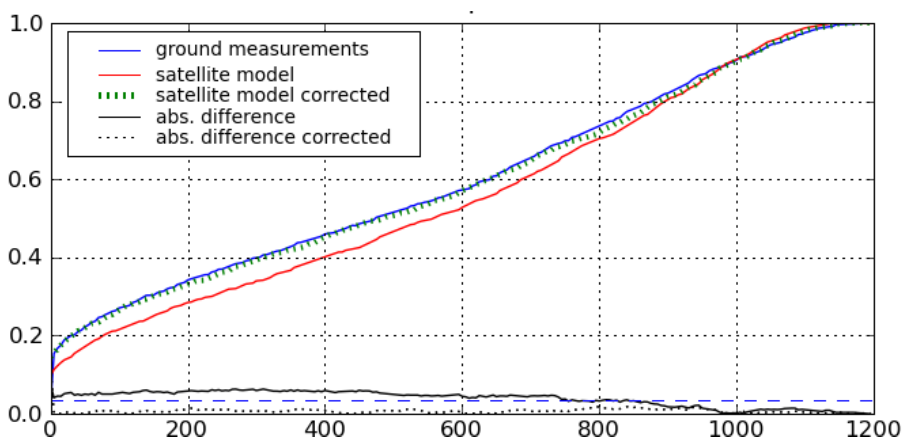

Fig. 1 Correction of DNI (W/m2) cumulative distribution of DNI values for Cordoba

5. Conclusions

The new SolarGIS dataset based on the utilization of multispectral data from Meteosat Second Generation satellite and daily values of aerosols from GEMS dataset provides high quality DNI data with relatively low values of all three deviation measures calculated at 29 ground observation sites in Europe and North Africa.

The further improvement of the satellite based data may be achieved by the use of high-quality ground measurements: both for decreasing the overall bias and better matching the distribution of DNI values. The enhancement is effective for mitigating of *systematic* problems in the satellite derived data such as under/over-estimation of local aerosol loads. In such cases the analysed methods may be good for adaptation of satellite derived DNI datasets for microclimatic conditions in complex environmental conditions that cannot be recorded in global solar irradiation and atmospheric datasets. The enhancement based on the fit of cumulative distribution of DNI values may be especially effective when specific situations such as extreme irradiance events are important.

The methods presented must be used carefully, as inappropriate use for *non-systematic deviations* or use of *less accurate ground data* may lead to accuracy degradation of the primary satellite-derived dataset.

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